Amendments to the Drawings:

The attached replacement drawing sheet 3/5 includes changes to Figs. 7C and 7D. This attached sheet of drawings replaces the original sheet 3/5.

In Fig. 7C, reference numeral "30" has been removed.

In Fig. 7D, reference numeral "30" has been removed.

Attachment: Annotated sheet 3/5
Replacement sheet 3/5

REMARKS

Amendments:

Claims 1, 8, 9, 12, and 15 have been amended. Claims 7, 13, 14, and 16-30 have been canceled. New claims 31-33 have been added. In amended Figures 7C-7D, the reference numeral "30" has been removed as it was extraneous and duplicative in identifying the region corresponding to the reference numeral "16." No new matter is added by these amendments to the Claims and Drawings.

The Applicants respectfully request reconsideration of the claims.

The Invention As-Claimed:

As recited in amended claim 1, the invention provides a carbon nanotube device. The device has a substrate including an aperture extending from a front surface to a back surface of the substrate. At least one pair of electrically conducting contact pads are disposed on a selected one of the front and back substrate surfaces and are separated by the aperture in the substrate.

A carbon nanotube catalyst region of a solidified vapor deposit is disposed on top of each of the contact pads on the selected substrate. The catalyst regions are exposed at the selected substrate surface. At least one carbon nanotube extends across the aperture and is accessible through the aperture from both the front surface and the back surface of the substrate. Each end of the carbon nanotube is located on top of an exposed catalyst region at the selected substrate surface.

Claim Rejections:

Claims 1-11 and 13-15 were rejected under 35 U.S.C. §102(b) as being anticipated by Brown et al., U.S. No. 6,297,063 (hereinafter "Brown").

The Examiner suggested that Brown teaches a carbon nanotube device having a support structure including an aperture extending from a front surface to a back surface of the structure. The Brown structure was said to have at least one carbon nanotube extending across the aperture and accessible through the aperture from both the front and back surface of the support structure.

Brown describes "in-situ growth of nanowires between two circuit substrates," (Col. 4, lines 11-12). In Brown Figs. 1A-1C there are shown two circuit substrates 10, 10' having contact pads 12a, 12b, 12a'12b' thereon (Col. 4, lines 13-14). A nucleation layer 26 is provided on each contact pad (Col. 4, lines 24-25). Nanowires 14a, 14b, 14c, etc., such as carbon nanotubes, shown in Brown Fig. 1C, are synthesized to vertically extend between the two substrates to provide "vertical interconnection" between the "upper and lower mating circuit substrates," (Col. 5, lines 15-23).

The invention as recited in amended claim 1 requires a substrate through which an aperture completely extends between two surfaces. As explained at ¶¶26-27 of the instant Specification, with a substrate including such an aperture, a nanotube can be synthesized to form a bridge across the aperture to make contact between two electrodes that are provided on a surface of the substrate. With this technique, selected arrangements of nanotubes can be formed between contact pads, across apertures, on a substrate. As explained at ¶28, gas or liquid can then be directed through the substrate itself for nanotube-based sensing or other applications. This enables a compact arrangement in which nanotube synthesis is incorporated with planar microfabrication to produce planar, substrate-based nanotube devices and systems, and allows for use of a microfabrication substrate directly in a nano-electromechanical application.

In the Brown passage cited by the Examiner, Brown teaches configurations for making a vertical electrical connection between two substrates, not for making an

electrical connection across an aperture on a single substrate as required by the claims. Brown provides no teaching or even hint at the formation of an aperture through the full thickness a substrate and a carbon nanotube bridge across the aperture and connected between catalyst regions on two contact pads on the substrate as required by the claims.

The Applicants note that aside from the Brown passage cited by the Examiner, Brown Figs. 6A-6C depict nanotube synthesis between horizontal circuit interconnections (Col. 7, lines 4-6). In this scenario, Brown teaches the formation of a nucleation layer 26 and blanket-coating of the nucleation layer with an insulating layer 102. "A horizontal slot" is then cut through the layer structure and nanowires are grown horizontally across the slot (Col. 7, lines 25-43).

The carbon nanotube device of the invention as recited in amended claim 1 requires at least one pair of contact pads separated by an aperture between two surfaces of a substrate, with a catalyst region on top of each pad and exposed at the substrate surface. In great contrast, in the Brown horizontal synthesis, the catalyst layer is not exposed at the substrate surface. As shown clearly in Brown Figs. 6A-6C, the catalyst layer is covered by a blanket coat of an insulating layer.

In Brown's arrangement, a nanotube 114 is to be synthesized from a side face of a catalyst layer which is exposed by the cutting of a slot 104. The upper insulating layer is employed in an effort to inhibit vertical growth of nanotubes and in an effort to encourage horizontal growth. The use of such a vertical growth preventing layer was at one time conventionally understood to be required.

But it has been discovered in accordance with the invention that the likelihood of success of Brown's arrangement in a nanotube growing across a slot from a first catalyst side face to a second catalyst side face is very low. As nanotubes grow, they tend to flop

around and then stick to a surface they eventually fall to and contact through Van der Waals forces. The Brown arrangement does not accommodate this behavior and requires that a nanotube "find" an end face of a catalyst layer .

The invention provides a discovery that carbon nanotubes can be synthesized horizontally without requiring the blanket vertical growth preventing layer employed by Brown. In the invention, each catalyst region is disposed fully exposed at a substrate surface. For example, as shown in Fig. 7C and Fig. 9 of the instant Specification, a catalyst region 26 atop each of two contact pads 16 is fully exposed, i.e., is not covered by other material layers. Then as shown in Fig. 7D of the instant application, a carbon nanotube 10 is synthesized between two of the exposed catalyst regions. Brown neither teaches nor suggests that a catalyst layer could be exposed at a substrate surface and instead requires that the catalyst layer be coated with a growth preventing layer.

In contrast, the exposed catalyst regions of the invention recited in claim 1 enables nanotubes to directly access planar catalyst region surfaces as the tubes are synthesized, and thus enable successful horizontal nanotube growth. This arrangement and the fabrication process of the invention overcome the severe limitations of the Brown arrangement with a discovery that a vertical growth layer is not only unnecessary but deleterious to successful nanotube growth. In that respect, Brown actually teaches away from the arrangement of the invention.

Thus both Brown nanotube arrangements fail to meet the requirements of the claims; neither Brown's vertical nanowire electrical connection between two substrates nor Brown's slotted horizontal nanotube synthesis provide the requirements of the claims. Brown never teaches or suggests how one might make an aperture through a substrate and provide a nanotube across the aperture, between two contact pads, with ends of the nanotube located on top of exposed catalyst regions on the substrate surface. In Brown's

first scenario, Brown is concerned solely with making electrical connections between two different substrates, and there is no teaching or suggestion for forming an aperture in a single substrate for nanotube synthesis across the substrate. In Brown's second scenario, Brown is concerned with synthesizing horizontal nanotubes by employing a blanket coating over a catalyst layer and requiring nanotubes to grow from end faces of the catalyst layer. There is no teaching or suggesting by Brown for forming an aperture through the substrate, and there is not even a hint that horizontal nanotube synthesis could be carried out with catalyst regions exposed on the substrate surface rather than blanket-coated by an upper layer.

Claims 2-15 and 31-33 depend from claim 1 and include all of the limitations of claim 1. Thus, for any combination of recited limitations in the dependent claims that are suggested by Brown, Brown fails to teach or suggest the fundamental limitations of claim 1 as included in all other claims.

For example, claim 2 requires a single-walled carbon nanotube; claim 3 requires a multi-walled carbon nanotube; claim 4 requires a semiconducting carbon nanotube; claim 5 requires a metallic carbon nanotube; and claim 6 requires a plurality of carbon nanotubes. Claim 15 requires a plurality of pairs of contact pads. For any specific carbon nanotube characteristic, number of nanotubes, or number or contact pads suggested by Brown, Brown fails to teach or suggest a substrate having an aperture through the substrate itself and a carbon nanotube bridge across the aperture and connected between catalyst regions that are exposed on the substrate and on top of contact pads on the substrate as required by the claims.

Claim 8 requires that the substrate be a semiconducting substrate. For any substrate employed by Brown, Brown requires either the use of two such substrates, between which nanotubes are vertically synthesized, or Brown requires the use of a slotted

substrate having a blanket layer covering a catalyst layer. In contrast, the claims require the use of one substrate through which is provided an aperture and on which are provided catalyst regions that are exposed on a substrate surface. Brown fails to teach or suggest such.

Claim 9 requires that the substrate include a membrane; claim 10 requires that the membrane be a silicon nitride membrane; and claim 11 requires that the membrane be a silicon dioxide membrane.

The Examiner here pointed to the Brown description at Col. 4, lines 24-37, suggesting that Brown reference numeral 26 refers to a membrane. The Applicants respectfully submit that this is not the case. Brown reference number 26 refers to a catalyst layer, i.e., a "catalytic nucleation layer 26," (Col. 4, line 24). Brown explains that the catalyst layer 26 is "disposed on the surface of each contact pad," (Col. 4, lines 24-25). The Brown catalyst layer is identified in Fig. 1A where the reference numeral 26 and associated reference line point to a layer on top of a contact pad 12b' that is on a substrate 10. The Brown catalyst layer is not a membrane – it is simply a layer provided on top of a contact pad on a substrate.

Fig. 7C-7D of the instant application illustrate example membranes in accordance with the invention. There is provide a membrane material 18 on top of a substrate 12. An aperture 14 is formed through the membrane, with a nanotube 10 synthesized between catalyst regions 26 on top of contact pads 16 provided on the membrane structure. Brown neither teaches nor in any way suggests a membrane in which is provided an aperture and across which a nanotube is provided. It appears that the Examiner has mistaken the Brown catalyst layer for a membrane.

Amended claim 12 requires that the substrate be aligned between a source of electrons and an electron detector for nanometer-scale transmission electron microscopy of the carbon nanotube.

Claim 12 was rejected under 35 U.S.C. §103(a) as being obvious over Brown in view of Bradley et al., U.S. Publication No. 20040043527 (hereinafter "Bradley"). Referring to Bradley ¶¶55-56, the Examiner suggested that Bradley teaches a support structure holding a nanotube and aligned with a source of electrons and an electron detector for transmission electron microscopy.

The Applicants respectfully submit that this is not the case. In Bradley Fig. 2, referred to at ¶¶55-56, there is shown a substrate 230. A nanotube 210 is shown laying on the surface of the substrate 230. A voltage supply 240 applies a voltage to the substrate 230. A second supply 250 provides the same voltage to the nanotube. A meter 260 measures the difference in current through the nanotube that results from exposure of the nanotube to an environment of interest. (¶¶55-56).

This electrical circuit and current measuring technique is not transmission electron microscopy as required by claim 12. Microscopy, by definition, involves forming a micro-scale image. In transmission electron microscopy (TEM), electrons are directed through a structure of interest and after passing through the structure, are collected at a detector. TEM is not an electrical circuit such as that shown by Bradley.

As explained in the instant specification at ¶27, it is generally recognized by those skilled in the art that nm-scale TEM resolution is required to enable sufficient precision in nanotube analysis. Such cannot be achieved if the transmitting electrons must traverse a substrate. It is discovered in accordance with the invention that the substrate aperture provided by the invention enables alignment of the substrate between a source of

electrons and an electron detector so that TEM can be carried out on a nanotube in place across an aperture in a substrate without the need to remove the nanotube from the substrate. No destruction of a nanotube under investigation is required to achieve nanometer-scale TEM resolution.

Neither Bradley, nor Brown, nor any combination of the two teach or even hint at transmission electron microscopy, let alone nanometer-scale transmission electron microscopy and how such could be carried out with a nanotube in place across an aperture on a substrate as required by the claim.

With this discussion the Applicants respectfully submit that the claims are in condition for allowance, which action is requested. If the Examiner has any questions or would like to discuss the amendments, she is encouraged to telephone the undersigned Agent at the number given below.

Fees for New Claims:

For	No. Filed		No. Paid		No. Extra	Sm/Lg Rate	FEE
Total Claims:	33	-	30	=	3	$25/$50	$150.00
NEW CLAIM FEE:							$150.00

Enclosed is a check in the amount of $150.00 to cover the new claim fee. If there are any other additionally required fees beyond those indicated above, or any credits, please apply such to Deposit Account No. 12-1760.

Respectfully Submitted

Date: June 15, 2006

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FIG. 7A

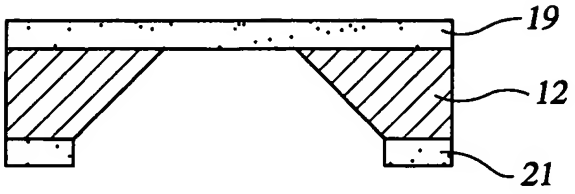

FIG. 7B

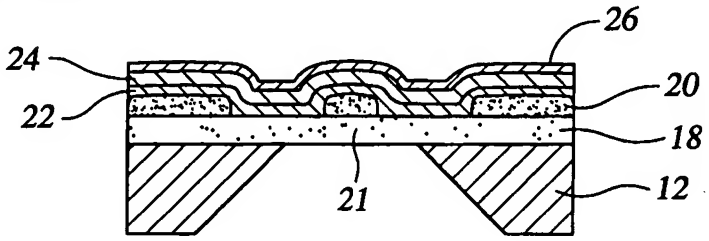

FIG. 7C

Reference Numeral 30 and lead line removed

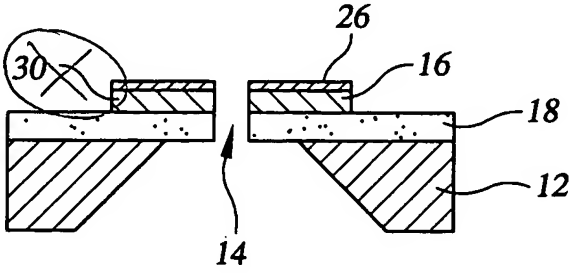

FIG. 7D

Reference Numeral 30 and lead line removed